

Short-Range Independent Microrobotic Platforms (SHRIMP)

HR001118S0048

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DARPA/MTO

Briefing prepared for SHRIMP Proposers Day

July 17, 2018



SETA Support
Ms. Michelle Young
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Dr. Kaiser Matin
Dr. Dick Cheng



SHRIMP Proposers' Day Agenda

Time	Topic	Speaker	Duration
8:30	Registration Sign-In	-	0:30
9:00	Logistics & Security	PSR/PSO	0:10
SHRIMP BAA			
9:10	SHRIMP Program Overview	Polcawich	1:20
10:30	Contracting and vehicle types	Blackstone	0:30
11:00	NIST first responder testing	Adam Jacoff (NIST)	0:30
11:30	Lunch break – submit FAQ notecards	-	1:00
SHRIMP Needs			
12:30	Poster set-up	-	-
12:30	TA1 Attendee Capability Summaries (optional)	TA1 attendees	0:30
13:00	TA2 Attendee Capability Summaries (optional)	TA2 attendees	0:30
13:30	TA3 Attendee Capability Summaries (optional)	TA3 attendees	0:30
SHRIMP POSTER SESSION			
14:00	FAQ responses	DARPA	-
14:00	Poster presentations	Poster presenters	2:00
16:00	Adjourn	-	



Goals

1. Present BAA to community – convey expectations for program
2. Q&A for program clarification
 - Collect questions (on note cards) that help DARPA better define the program
 - Gov't team will generate answers during lunch and after session
 - Review answers after the poster session
 - Publish Q&As in a FAQ attached to the SHRIMP BAA fedbizopps site
3. Poster session – promote and facilitate collaboration and comprehensive team forming



SHRIMP Objective

SHRIMP will develop and demonstrate, through a series of Olympic inspired competitions, multi-functional micro-to-milli scale robotic platforms with a focus on untethered mobility, maneuverability, and dexterity. To achieve this goal, SHRIMP will also provide foundational research in the area of micro-actuator materials and energy efficient power systems for extremely SWaP-constrained microrobotic systems.

The microrobotic platform capabilities enabled by SHRIMP will provide the DoD with significantly more access and capability to operate in small spaces that are practically inaccessible to today's state-of-the-art robotic platforms. Such capability will have impact in search and rescue, disaster relief, infrastructure inspection, and equipment maintenance, among other operations.



SHRIMP Program Structure

Three technical areas (TAs)

- TA1: Actuator Materials and Actuator Mechanism Development
 - TA2: Integrated Multi-Mode Power Solutions
 - TA3: Untethered Mobility Platforms (Controlled Unclassified Information, CUI and or/ Controlled Technical Information, CTI)
-
- Proposers can address one, multiple, or all technical areas per proposal
 - Multiple awards anticipated for each TA

Three 12-month phases

- Phase 1: Demonstrate scientific feasibility
- Phase 2: Demonstrate improved performance at scale
- Phase 3: Assess system performance via micro Olympics-styled competitions
 - TA1s and TA2s will be teamed for Phase 3



Teaming

- Teaming for an individual TA or across multiple TAs is welcome and in many cases encouraged
- We expect partnerships to form which include entities that work within the national defense enterprise and traditional research teams.
- We intentionally are hoping for teaming that otherwise wouldn't happen so that the final result is closer to where the impact will be needed within the defense enterprise.
- Phase 3 for TA1 and TA2 will be combined through Associate Contractor Agreements (details in later slides)
- TA3 does have CUI/CTI requirements.
 - University teams can still contribute to the design of the TA3 by designing specific features
 - Final designs are expected to be at a location that can handle CUI/CTI data.



Controlled Unclassified Information (CUI) and Controlled Technical Information (CTI)

- Controlled Technical Information (CTI) is defined as technical information with military or space application that is subject to controls on its access, use, reproduction, modification, performance, display, release, disclosure, or dissemination
- CTI is to be marked with one of the distribution statements B through F, in accordance with Department of Defense Instruction 5230.24, "Distribution Statements on Technical Documents"
- The Contractor shall protect CTI in accordance with DFARS 252.204-7012
- Contractor information systems shall be subject to the security requirements in National Institute of Standards and Technology (NIST) Special Publication (SP) 800-171 "Protecting Controlled Unclassified Information in Nonfederal Information Systems and Organizations"
- DARPA can provide guidance on how to implement 800-171 controls
- As part of their efforts on this program, TA3 performers **MUST** be able to meet all CTI safeguarding requirements
- As part of their efforts on this program, only the TA1 and TA2 performers in Phase 3 that cross the CTI threshold (see definition) **MUST** be able to meet all CTI safeguarding requirements

Performers uncertain about whether a given dataset contains CTI should request guidance from DARPA



Definition of CTI for SHRIMP

Combined TA1 and TA2 Phase 3 Entries

- All entries that have untethered ambulation (e.g. ground or air mobility) will be considered similar to TA3 untethered mobility platforms and therefore must follow the restrictions below

TA3 Tethered Mobility Platforms

- All platforms exhibiting multi-mode mobility (e.g. crawling and jumping or crawling and flying) that are relying on tethering for power are considered CTI
- All platforms exhibiting multi-functions (e.g. mobility combined with collision avoidance or detection sensors) that are relying on tethering for power are considered CTI
- All detailed design data (e.g. detailed CAD drawings, bill of materials, assembly instructions, performance simulations, etc.) of platforms considered CTI are considered CTI
- All specific details of communications, control and/or preprogramming of the platforms considered CTI are considered CTI

TA3 Untethered Mobility Platforms

- All detailed untethered design data (e.g. detailed CAD drawings, bill of materials, assembly instructions, performance simulations, etc.) are considered CTI
- All detailed untethered performance data (e.g. runtime, range, speed, etc.) are CTI when tied to a specific operating environment (e.g. "range of X on a flat surface A", "speed of Y when moving on a surface B", etc.)
- All specific details of communications, control and/or preprogramming of the untethered platform are considered CTI

Performers uncertain about whether a given dataset contains CTI should request guidance from DARPA



What is not CTI in SHRIMP

TA1 Actuator Materials and Actuator Mechanism Development

- All aspects of Phase 1 and 2 of TA1

TA2 Integrated Multi-Mode Power Solutions

- All aspects of Phase 1 and 2 of TA2

TA3 Tethered Mobility Platforms

- All platforms with single functions or single-mode mobility that rely on tethering for power and other functions (e.g. control)

Performers uncertain about whether a given dataset contains CTI should request guidance from DARPA



SHRIMP Goals

TA1: Efficient Mobility

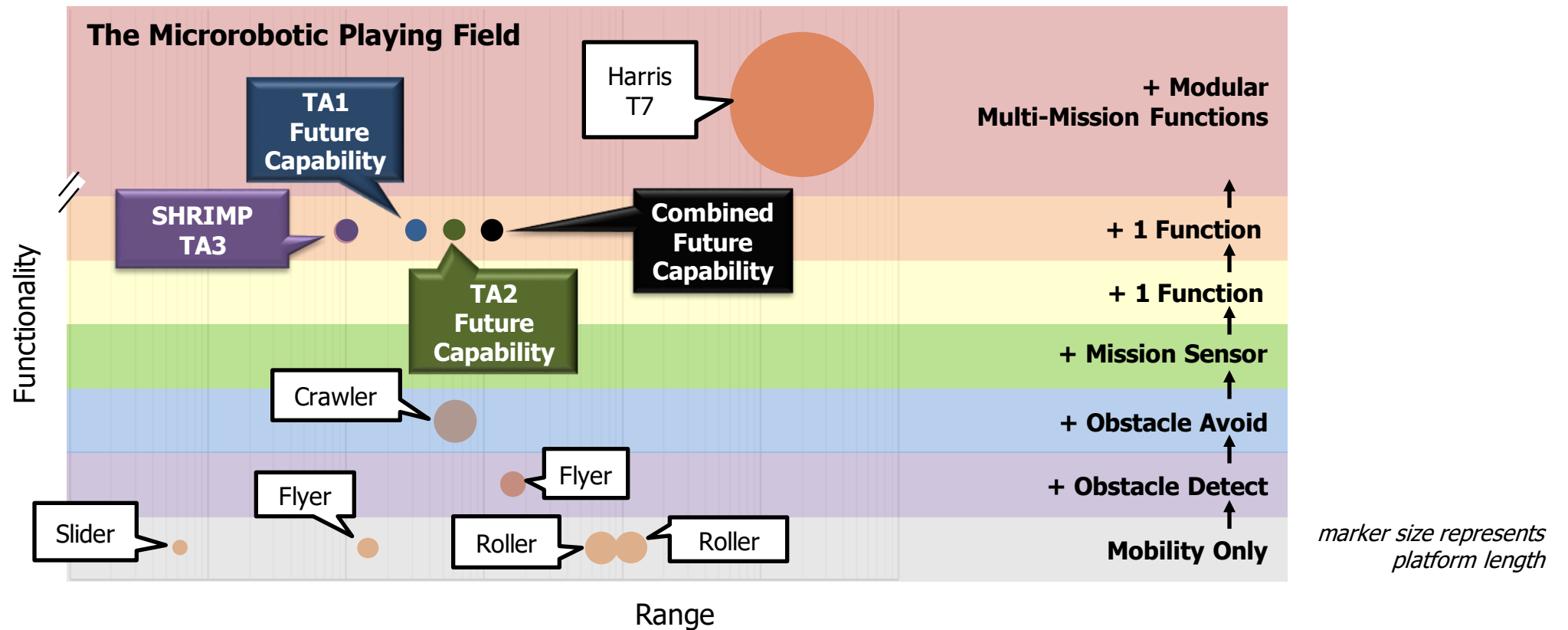
Actuators and actuator mechanisms

TA2: Compact Power

High-voltage, long-lasting power systems

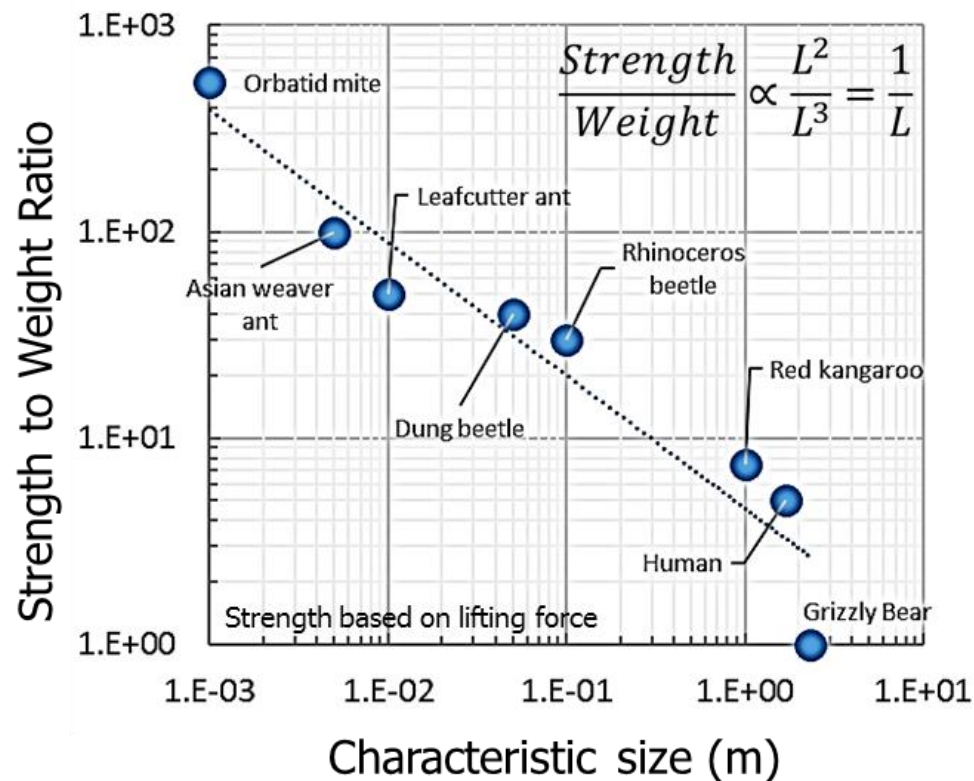
TA3: Untethered Platforms

Develop robotic platforms with volume $< 1 \text{ cm}^3$

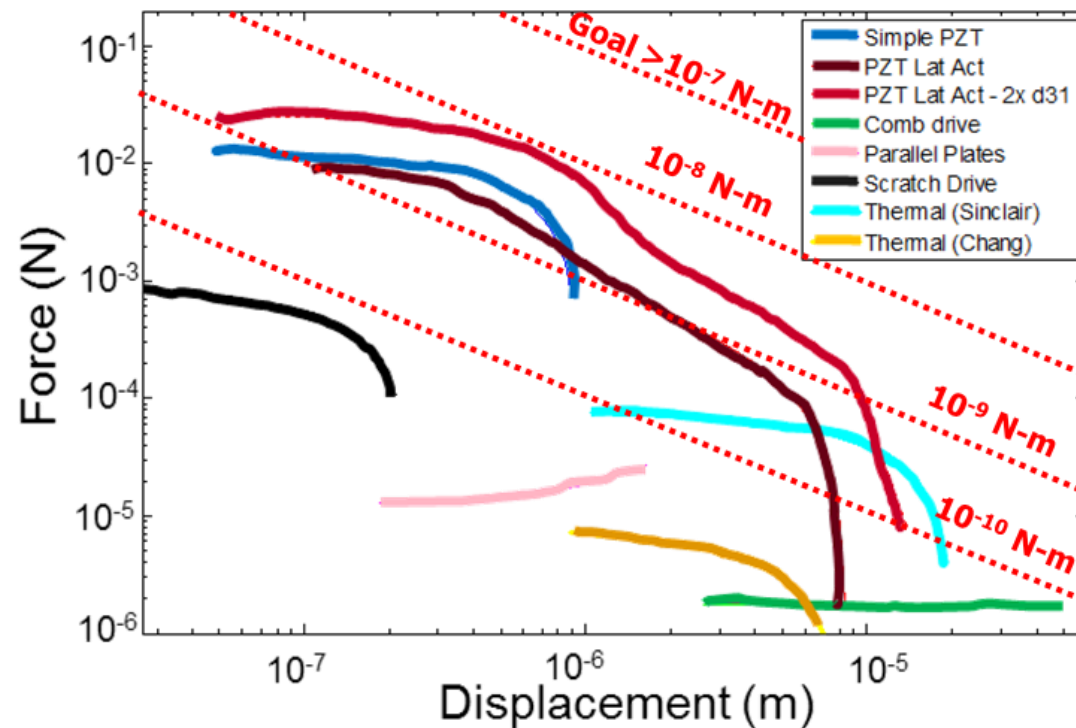


Extend the functionality and range by advances in materials, actuators, & integrated power systems

Specific Strength vs. Size



Force-displacement vs. Actuator Material



Miniaturization offers opportunity to increase strength to weight ratio



Technical Area 1: Actuator Materials and Actuator Mechanism Development

- Develop actuator materials and mechanisms capable of maximizing work densities (work output capability per unit volume) of $\geq 1 \text{ J/cm}^3$ at the system level
- **Phase 1:** material advancements in force displacement characteristics that can be evaluated with fairly simple structures (e.g. cantilevers)
- **Phase 2:** focus shifts to actuator mechanisms; descriptions should include specific details of the overall approach (e.g. the use of joints, gearing, etc.) and how it will result in successful performance in Phase 3
- **Phase 3** (*combined TA1/TA2 team competitions*): positional control of the mechanism will be important, thus both static and dynamic displacements along with positional accuracy should be provided
- Approaches that rely on mechanical transmission to convert force, displacement, and/or velocity/frequencies must clearly describe how the mechanism will interface with the actuator and external loads/structures
- Approaches that capture and store energy that is released in an impulse event are allowable; however, actuator frequencies should be able to operate at frequencies $\geq 20 \text{ Hz}$



TA1 Metrics Table (Phases 1 & 2)

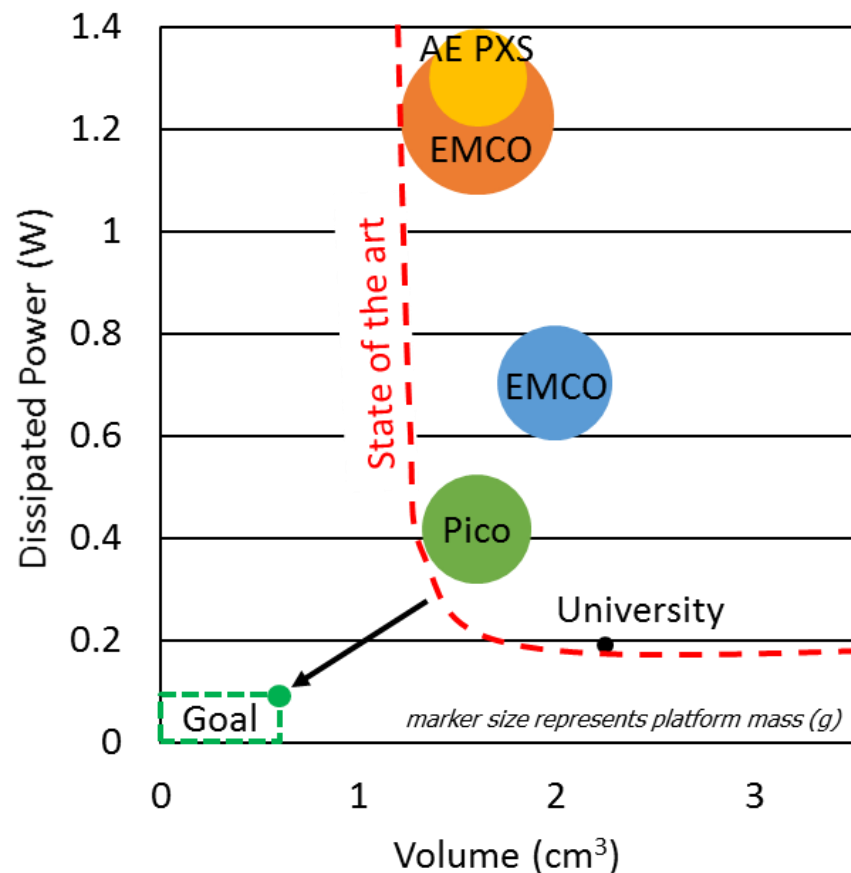
Metric	Phase 1 – Actuator Materials	Phase 2 – Actuator Mechanism
Volume	1 cm ³ *	2 cm ³ **
Weight	2 g *	1 g **
Largest dimension	N/A	< 2 cm
Operating frequency	N/A	< 500 kHz
Performance	Force-displacement > 10 ⁻⁷ Nm *	Work density > 1 J/cm ³ **
User Defined Actuator Mechanism Metric	N/A	User defined

TA1 will be combined with TA2 for Phase 3. Phase 3 has separate, combined metrics.

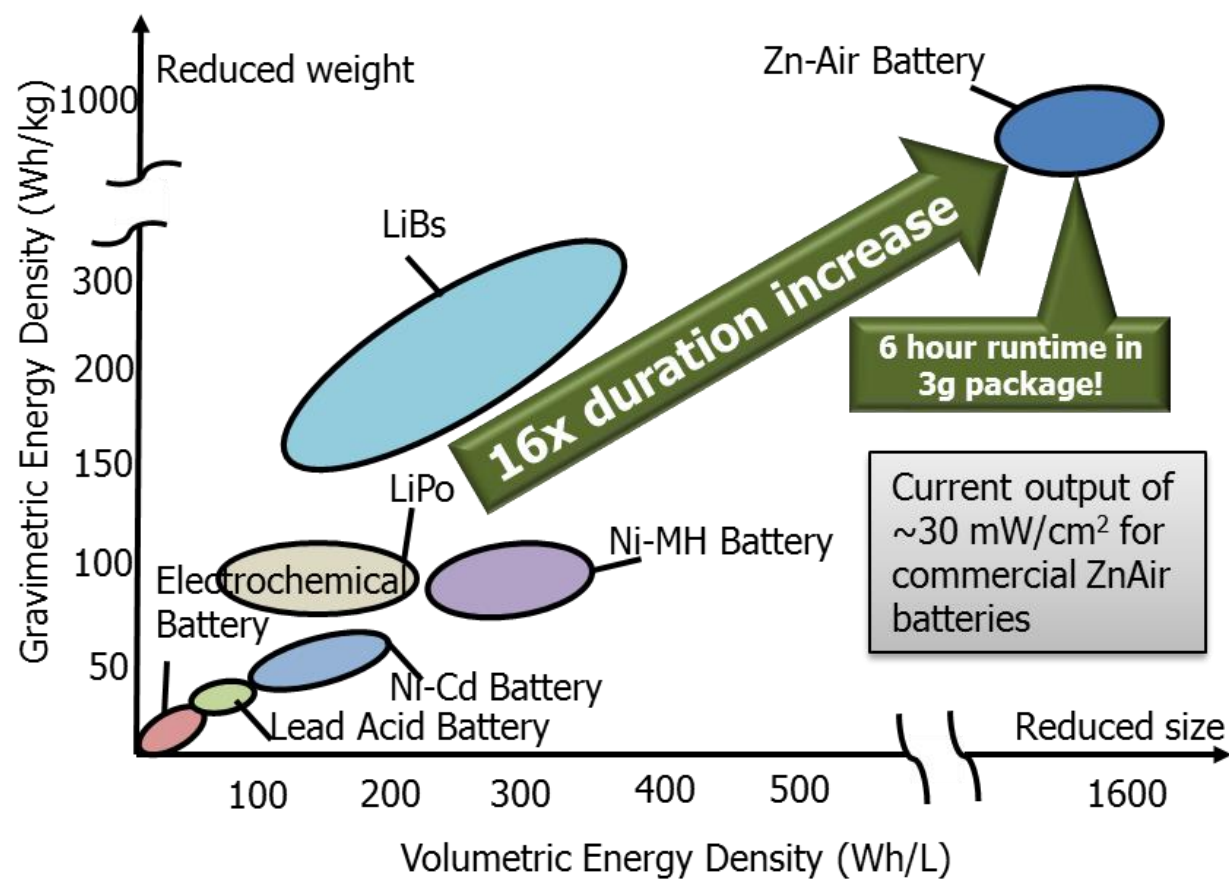
* Demonstrated using actuator material system only

** Demonstrated using actuator material plus mechanism

Power Converters Capable of 200V, 3 mA



Energy Density Landscape



Compact, energy efficient power converters and higher current output in primary batteries required



Technical Area 2: Integrated Multi-Mode Power Solutions

Two tracks:

- Track A – Integrated Power Systems
 - Develop high voltage power sources (0.05 to 3kV) to drive micro-to-milli scale actuators such as electrostatic, piezoelectric, and dielectric elastomer actuators
 - The high voltage converter should be able to operate at relevant frequencies and with an appropriate bandwidth (DC to operating frequency)
 - For resonant transformers, the resonance frequency of the transformer does not have to match the operational frequency of the high voltage output.
- Track B – Batteries
 - High power and high energy battery solutions with voltage outputs ranging from 1.2 to 3.7V.
 - Current lithium-ion and lithium-polymer technologies at mm scale have high power density but limited energy density while commercial Zn-air batteries have higher energy densities but have a limited power density or discharge rate



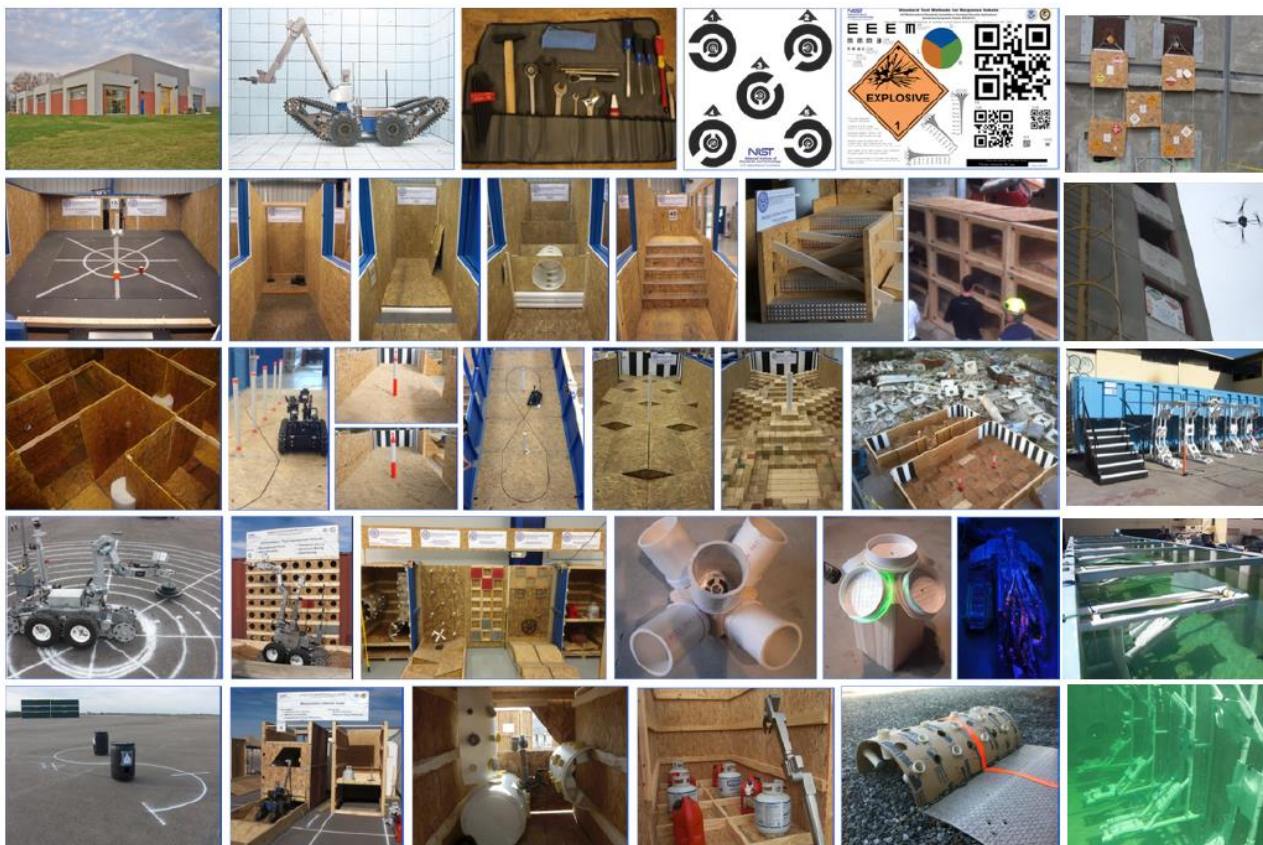
TA2 Metrics Table (Phase 1 & 2)

	Metric	Phase 1	Phase 2
Both tracks	Volume	<0.333 cm ³	<0.188 cm ³
	Length	1 cm	0.7 cm
	Weight	1 g	0.5 g
Track A: Int. Power System	Delivered Average Power	100 mW	100 mW
	Voltage	0.05 - 3 kV	0.05 - 3 kV
	Frequency	> 20 Hz	> 40 Hz
	Duty Cycle	50%	50%
	Duration of Power	> 60 s	> 300 s
Track B: Battery	Height	< 10 mm	< 5 mm
	Delivered Power	200 mW	200 mW
	Duration of Power	> 2.5 hr	> 1.5 hr
	Specific Energy Density	500 W-hr/kg	600 W-hr/kg
	Volumetric Energy Density	1500 W-hr/L	1600 W-hr/L
	Operating Temp	-	Room Temp → 60°C

TA2 will be combined with TA1 for Phase 3. Phase 3 has separate, combined metrics.

Standard Test Methods for Response Robots

Mobility
Dexterity
Endurance
Sensors
Radio Comms
Durability
Logistics
Safety
Autonomy
Proficiency



Sensing & Autonomy



Levels of Autonomy	
1	No Automation • <i>Tethers</i>
2	Low Automation • <i>Wireless remote control</i> • <i>No pre-programming</i>
3	Medium Automation • <i>Pre-programmed waypoints</i> • <i>User observes & corrects</i>
4	High Automation • <i>Pre-programmed mission</i> • <i>User observes, minimal correction</i>
5	Full Automation • <i>Pre-programmed mission</i> • <i>No user intervention</i>

Leverage emerging platforms, autonomy practices, and TA1 / TA2 to extend capability of SHRIMP



Technical Area 3: Untethered Mobility Platforms (CUI/CTI)

- Develop and demonstrate multi-functional mm-to-cm scale robotic platforms
- Untethered robotics platforms with volume less than 1 cm³ and a longest dimension less than 1 cm
- Encouraged to take advantage of existing developments in low power sensors, advanced CMOS ASICs and integrating advancements in TA1 and TA2 to create robotic platforms that can demonstrate complex functions
- Adoption of technologies from TA1 and TA2 may be undertaken using Associate Contractor Agreements (ACAs)
- TA3 teams will be evaluated on their progress towards Phase 3 capability in Phase 2 through the requirement to perform at least one competition in an untethered configuration



TA3 Metrics Table by Phase

Metric	Phase 1	Phase 2	Phase 3
Largest dimension	2 cm [†]	1 cm ^{††}	1 cm ^{†††}
Weight	2 g [†]	1 g ^{††}	1 g ^{†††}
Duration of Mobility	300 s [†]	180 s ^{††}	180 s ^{†††}
Cost of Transport	< 100 [†]	< 50 ^{††}	< 50 ^{†††}
Number of competitions	-	1 ^{††}	4 ^{†††}
User Defined System Metric(s)	User defined	User defined	User defined

† Tethered demonstration

†† Untethered demonstration

††† Pre-programmed demonstration

$$COT = \frac{E}{mgd} = \frac{P}{mgv}$$



- Head-to-head competition to assess capabilities
- No tethers (physical, magnetic, optical, or wireless)
- TA1/TA2 will be teamed together through associate contractor agreements (ACAs)
- Different systems can be entered into different competitions, but higher rankings will be given to systems competing in multiple competitions
- Top three competitors in each competition and cumulatively across all competitions will get non-monetary award certificates

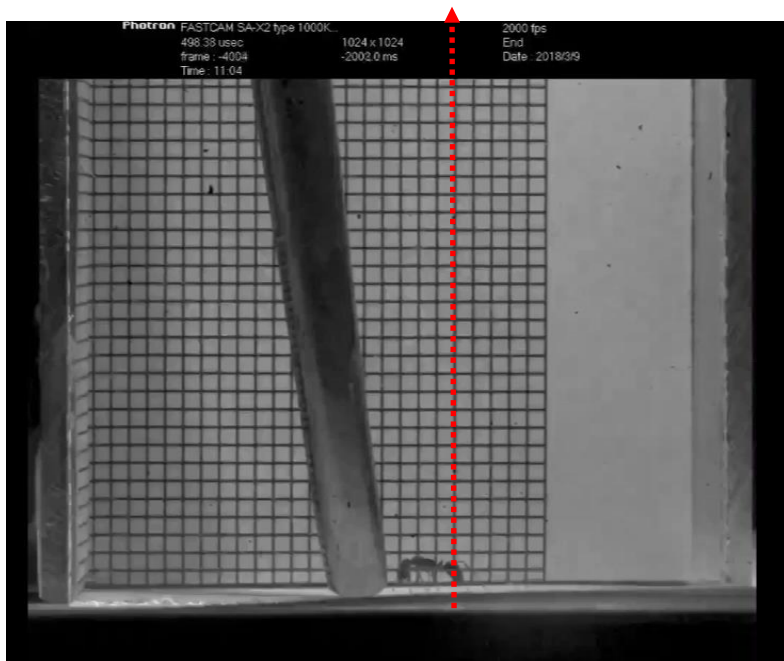
TA1/TA2 Competitions (Non-CUI/CTI)

- High jump
- Long jump
- Shot put
- Weightlifting
- Tug-of-war

TA3 Competitions (CUI/CTI)

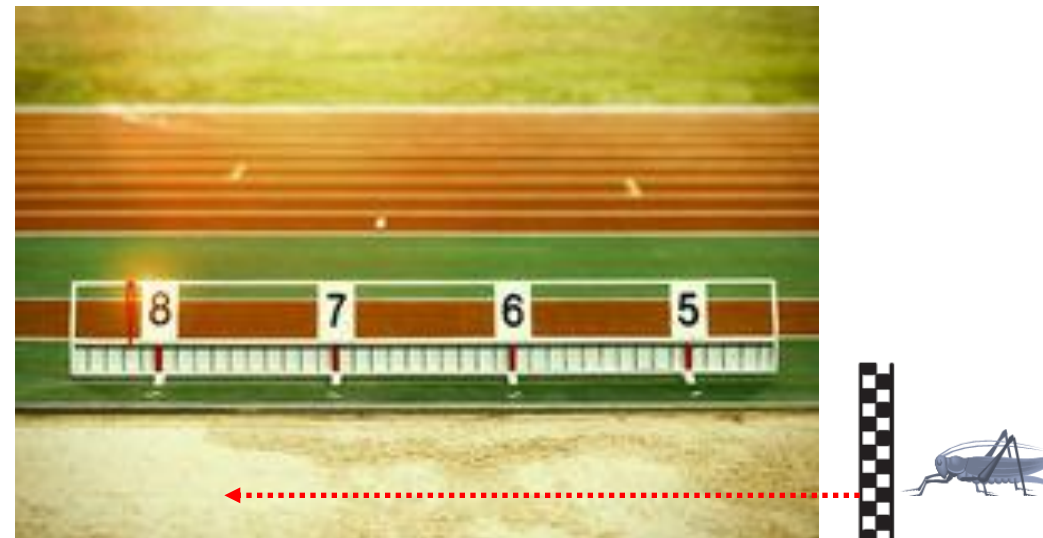
- Rock piling
- Vertical ascent
- Steeplechase
- Biathlon

High jump



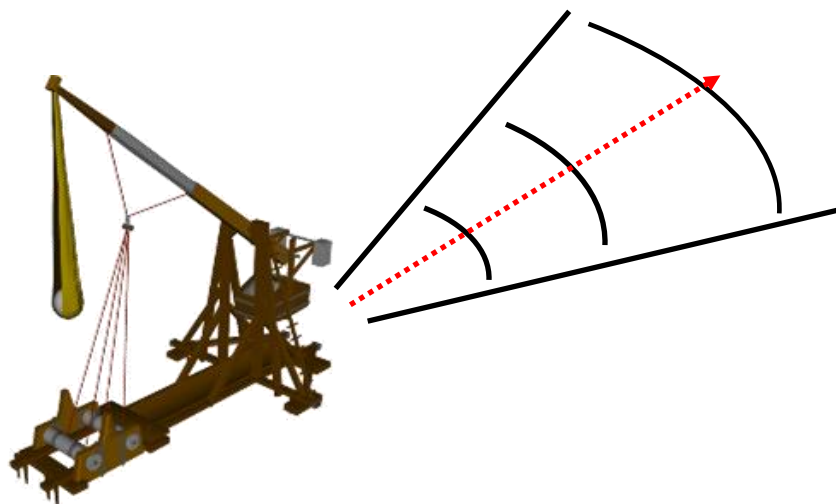
- Best 3 out of 5 jumps averaged
 - Minimum 5 cm to qualify
- Judging Criteria:
 - Vertical distance
 - Survivability

Long jump



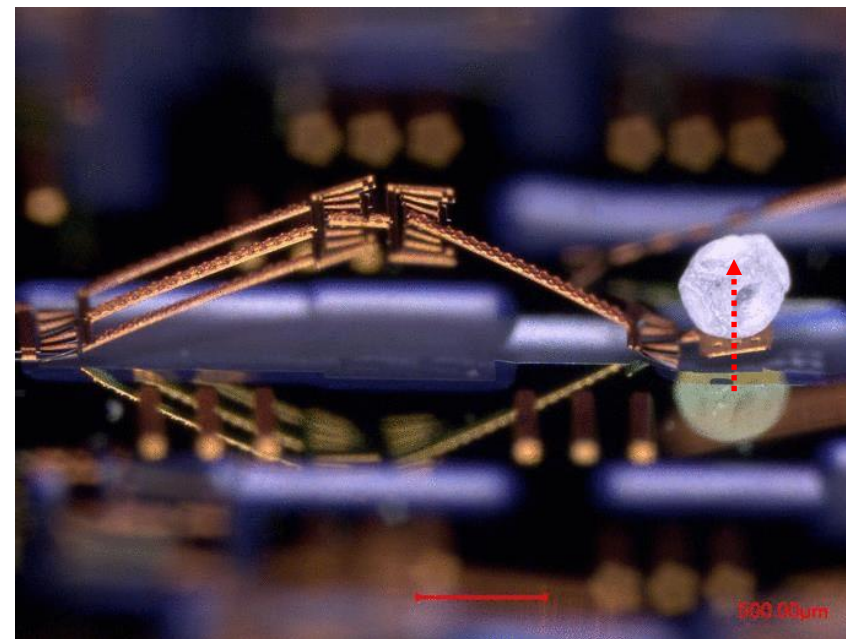
- Best 3 out of 5 jumps averaged
 - Minimum 5 cm to qualify
- Judging Criteria:
 - Horizontal distance
 - Survivability

Shot Put

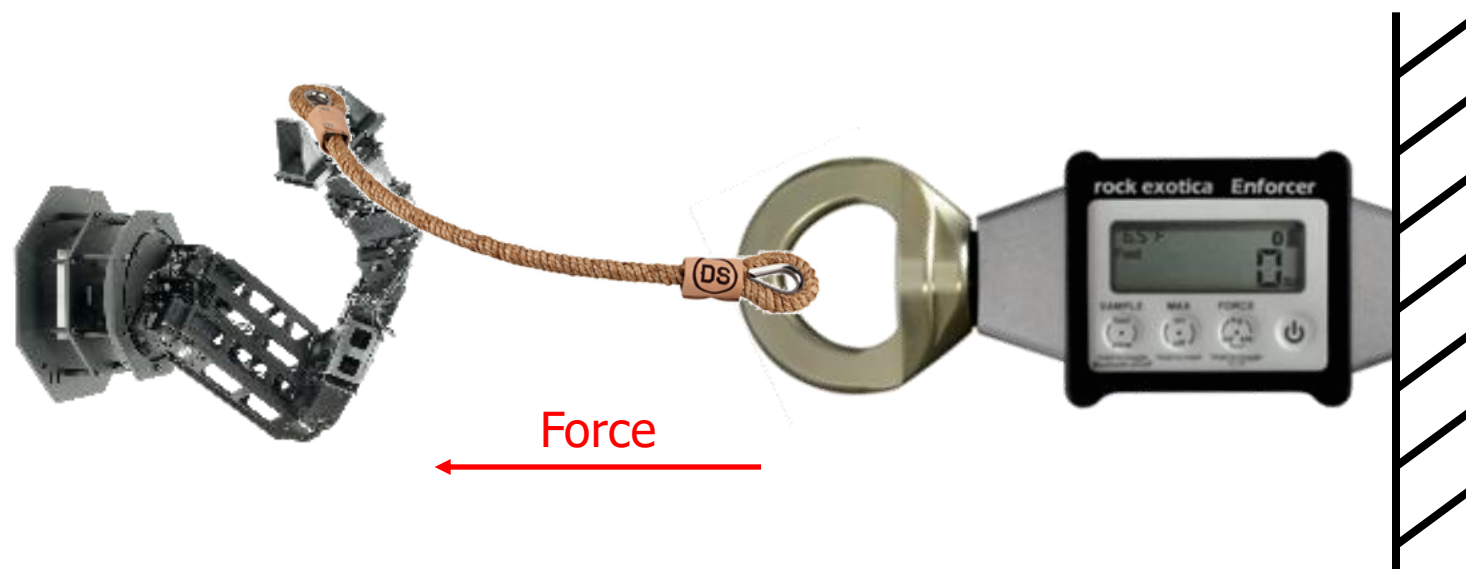


- Best 3 out of 5 throws averaged
 - Minimum 2 cm for 5g shot
 - Minimum 10 cm for 1g shot
- Judging Criteria:
 - Horizontal distance

Weightlifting

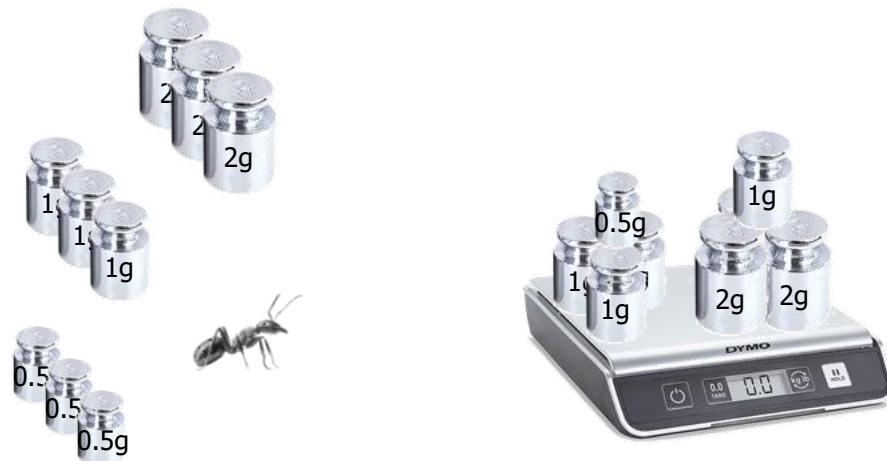


- Progressively larger masses until system fails to lift
- Judging Criteria:
 - Max lift weight
 - Vertical lift distance
 - Duration of lift



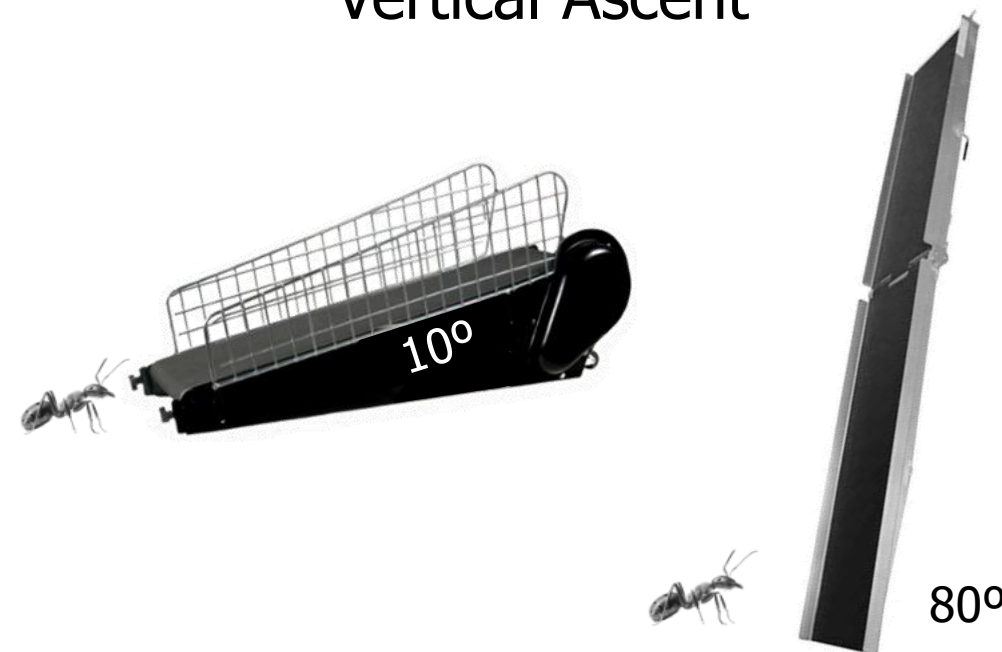
- Best 3 out of 5 tugs averaged
 - Minimum blocking force of 25 mN to qualify
- Judging Criteria:
 - Blocking force
 - Duration of tug

Rock Piling



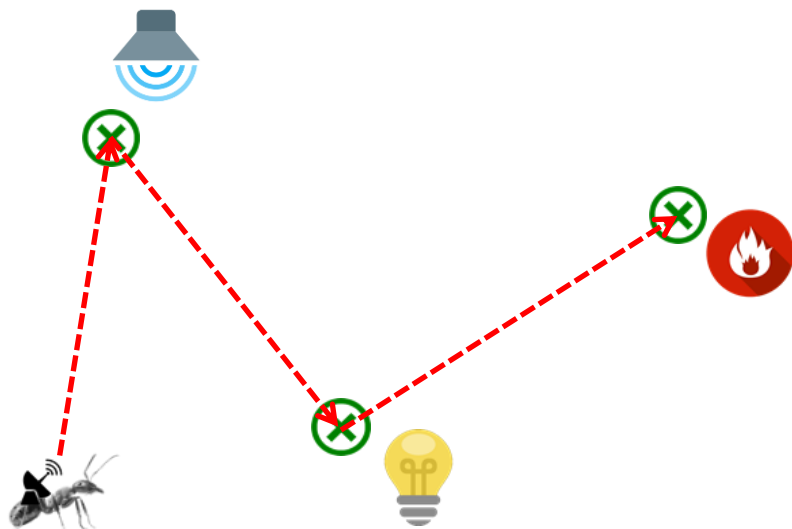
- Individual weights from 0.5-2.0 g
- Minimum of two layers
- Three attempts allowed
- Judging Criteria:
 - Total weight stacked
 - Number of layers

Vertical Ascent



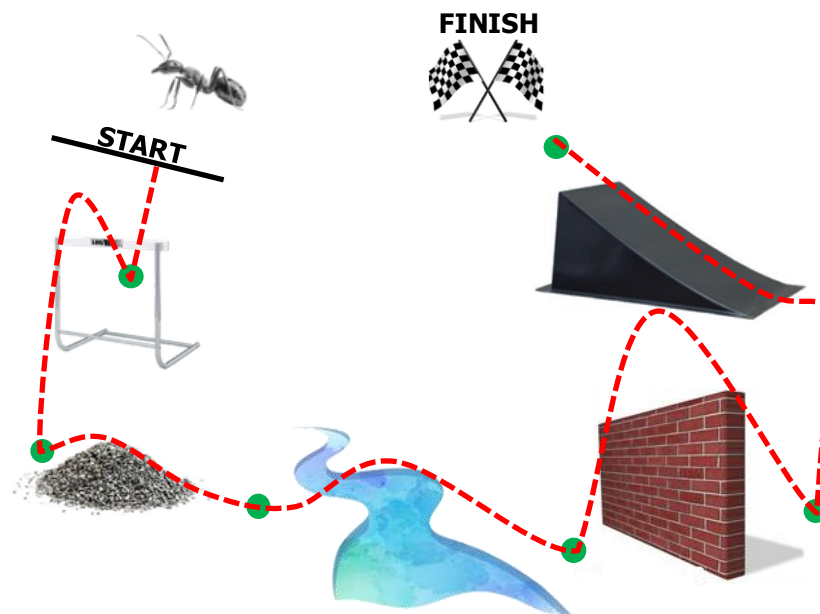
- Two inclines must be attempted:
 - Shallow: 10m minimum at 10°
 - Steep: 1m minimum at 80°
- Three attempts allowed
- Judging Criteria:
 - Total vertical distance traveled

Biathlon



- Choice of 3 beacon types
 - Light, sound, temperature
- Three attempts allowed
- Judging Criteria:
 - Number of cleared waypoints
 - Total distance traveled
 - Time

Steeplechase



- Traverse course of hurdles, gaps, steps, etc.
- Three attempts allowed
- Judging Criteria:
 - Number of cleared obstacles
 - Total distance traveled
 - Time



Micro Olympic-style Competition Metrics Table

Open Micro Olympic-style Competition	TA1/2 Phase 3 Objective
Volume	1 cm ³ ‡
Weight	1 g ‡
High Jump	> 5 cm
Long Jump	> 5 cm
Weightlifting	> 10 g
Shotput	1 g @ 10 cm
	5 g @ 2 cm
Tug of War	> 25 mN

‡ Combined TA1 actuator and TA2 power source

Note: A remote signal will be allowed to initiate motion for the competitions and will not be considered a tether. A remote signal is not required to initiate motion if another method is preferable.

CUI Micro Olympic-style Competition	TA3 Phase 3 Objective
Rock Piling	2-g weights, 2 layers
Steeplechase	2 obstacles, 5m
Biathlon	2 sensors, 80% POD*, 5m
Vertical Ascent	10 m @ 10°, 1 m @ 80°

* POD: probability of detection



Associate Contractor Agreements

- The rapid, collaborative Phase 3 path will require open and frequent sharing of information generated under and relevant to the SHRIMP program
- To facilitate collaboration, all performer contracts will include an ACA clause for portions of the contracts requiring joint participation between the TAs (i.e. for TA1s with TA2s, and TA3s with TA1s and/or TA2s)
- This provision will become a material requirement for any TA1 and TA2 contracts awarded as a result of this BAA
- The ACA clause will include the basis for sharing information, data, technical knowledge, expertise and/or resources essential to the integration of the SHRIMP program technical areas and tracks
- This clause will ensure appropriate coordination and integration of work by SHRIMP contractors and ensure compatibility between actuators, power systems, and platforms
- Without exception, all ACAs must be in place at the time of contract award

An ACA is an agreement between performers that specifies requirements for the performers to share information, data, technical knowledge, expertise, and/or resources



Program Budget and Schedule

	Estimated Budget	Phase 1 Start	Phase 2 Start	Phase 3 Start	Olympic-style Evals
TA1: Actuators	\$9-12M	March 2019	March 2020	March 2021	February 2022
TA2: Power	\$4-6M				
TA3: Platforms (CUI/CTI)	\$10-14M				
Total	\$23-32M				

- Two programs reviews per phase to facilitate inter-TA discussion
- Phase transition information required at the 10.5 month mark of Phases 1 & 2



Scheduled Program Milestones

	Phase 1	Phase 2	Phase 3
TA1 (6.1)	Successful demonstration of actuator materials achieving the metrics set forth in the TA1 metric table in the BAA No CUI Restrictions	Successful demonstration of actuator mechanisms achieving the metrics set forth in the TA1 metric table in the BAA No CUI Restrictions	Using an Olympic-inspired competition with competitions listed in the combined TA1 and TA2 metric table in the BAA, teams will compete to showcase the capabilities of actuator systems using combinations of actuator mechanisms and compact power sources CUI Restrictions May Apply (see CUI Guide)
TA2 Track A (6.1)	Successful demonstration of a compact, high voltage converter achieving the metrics set forth in the TA2 metric table in the BAA No CUI Restrictions		
TA2 Track B (6.1)	Successful demonstration of a compact power source achieving the metrics set forth in and TA2 metric table in the BAA No CUI Restrictions		
TA3 (6.2)	Successful demonstration of a tethered microrobotic platform achieving the metrics set forth in the TA3 metric table in the BAA CUI Restrictions Apply	Successful demonstration of an untethered microrobotic platform achieving the metrics set forth in the TA3 metric table in the BAA CUI Restrictions Apply	Using an Olympic-inspired competition with competitions listed in the TA3 Phase 3 metric table in the BAA, teams will compete to showcase the capabilities of untethered, pre-programmed microrobotic platforms CUI Restrictions Apply



TA1 & TA2

- All phases: quarterly technical and monthly financial reports
 - TA1 and TA2 technical reports should include details on material processing, fabrication, component/mechanism design, and device data
- Phase 2: functional prototype for independent government evaluation
- Phase 3: functional prototype of combined actuator-power system(s), specifications, and operating instructions for each system competing in the Olympic-themed competitions
- Final report that captures all key aspects of the program and include all pertinent material, design, simulation, and experimental data

TA3

- All phases: quarterly technical and monthly financial reports
 - TA3 technical reports should capture key elements for the platforms including but not limited to mass (m), power output (P), and efficiency (η) and include detailed robot configuration and specifications
- Phase 3: a functional prototype, specifications, operating instructions, and power/weight/cost breakdown for each platform competing in the Olympic-themed competitions
- Final report that captures all key aspects of the program and include all pertinent material, design, simulation, and experimental data



SHRIMP Proposal Evaluation Criteria



SHRIMP Evaluation Criteria (1/4)

Review and Selection Process:

- DARPA will conduct a scientific/technical review of each conforming proposal
- Proposals will not be evaluated against each other since they are not submitted in accordance with a common statement of work

SHRIMP Evaluation Criteria:

- Proposals will be evaluated using the following criteria, listed in descending order of importance:
 1. Overall Scientific and Technical Merit
 2. Potential Contribution and Relevance to the DARPA Mission
 3. Cost Realism



SHRIMP Evaluation Criteria (2/4)

Overall Scientific and Technical Merit

- The proposed technical approach is innovative, feasible, achievable, and complete.
- Task descriptions and associated technical elements provided are complete and in a logical sequence with all proposed deliverables clearly defined such that a final outcome that achieves the goal can be expected as a result of award.
- The proposal identifies major technical risks and planned mitigation efforts are clearly feasible.
- Proposals highlight the traceability of the proposed actuator, power source, and platform technology to untethered, independent operation.
- While tethered (including physical, optical, magnetic, and wireless) operation is allowable during development in the early phases of the program, the ultimate program goal is to demonstrate untethered operation leveraging the advances in energy storage and efficiency that will be discovered during SHRIMP. A realistic, logical path to untethered operation should be described in the proposal, as well as risk reduction strategies and planned developments that make the path possible.
- Similar efforts completed/ongoing by the proposer in this area are fully described including identification of other Government sponsors.
- The proposed technical team has the expertise and experience to accomplish the proposed tasks



SHRIMP Evaluation Criteria (3/4)

Potential Contribution and Relevance to the DARPA Mission

- The potential contributions of the proposed effort are relevant to the national technology base. Specifically, DARPA's mission is to make pivotal early technology investments that create or prevent strategic surprise for U.S. National Security.
- Proposers should highlight the contribution of their proposed research to the DARPA mission.
- Proposers should also describe previous efforts and their impact on DARPA's mission and on U.S. National Security, as relevant.
- A history of transitioning government-funded technologies to supporting national interests will have a positive impact on proposal evaluation, while transitioning government-funded technology or related technologies to foreign entities or through foreign influence will have a negative impact on proposal evaluation.
- The proposer clearly demonstrates its capability to transition the technology to the research, industrial, and/or operational military communities in such a way as to enhance U.S. defense.
- The evaluation will take into consideration the extent to which the proposed intellectual property (IP) rights structure will potentially impact the Government's ability to transition the technology.



SHRIMP Evaluation Criteria (4/4)

Cost Realism

- The proposed costs are realistic for the technical and management approach and accurately reflect the technical goals and objectives of the solicitation.
- The proposed costs are consistent with the proposer's Statement of Work and reflect a sufficient understanding of the costs and level of effort needed to successfully accomplish the proposed technical approach.
- The costs for the prime proposer and proposed subawardees are substantiated by the details provided in the proposal (e.g., the type and number of labor hours proposed per task, the types and quantities of materials, equipment and fabrication costs, travel and any other applicable costs and the basis for the estimates).
- It is expected that the effort will leverage all available relevant prior research in order to obtain the maximum benefit from the available funding.
- For efforts with a likelihood of commercial application, appropriate direct cost sharing may be a positive factor in the evaluation.
- DARPA recognizes that undue emphasis on cost may motivate proposers to offer low-risk ideas with minimum uncertainty and to staff the effort with junior personnel in order to be in a more competitive posture. DARPA discourages such cost strategies.



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Thank you for your interest in SHRIMP!

The technical POC for this effort is:

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